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Use of Aerial Photographs in Estimating Forest Drain

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Aerial Photographs
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by

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INTRODUCTION

THE NATIONWIDE FOREST SURVEY now under way was undertaken to determine the status of the Nation's forest resource. The purpose of the survey is, in brief, to find out how much timber there is and where it is, the drain on this resource, and how much of the drain is being replaced by new growth.

The most difficult of these to estimate is drain.

Under the standard forest-survey method, drain is estimated by gathering production data from sawmills, pulp mills, and the like, and adding in logging waste. But many mills are in isolated places, their products are diverse, and timber products are moved in and out of the area across state lines. Besides, some mills do not keep records of the kind of information needed; some are reluctant to reveal

their production data. After production data are obtained, further study is needed so they can be adjusted to account for the many variations in wood utilization. Drain due to fire, wind, and other causes must be accounted for.

As a result of all these factors, reliable estimates of forest drain are difficult to make.

One possible alternative is to measure periodic drain by re-examining a series of sample plots. Such a method has been described by J. G. Osborne.[1] With his method, called the "continuous-inventory" system, changes due to cutting, growth, fire, etc., would be determined by periodically re-examining a series of sample areas. He proposed use of a large number of ½-mile strips. These strips would be classified in the initial inventory by stand classes, and they would be reclassified periodically after that. Estimates of volume removed would be made by subsampling stand classes.

This method was tested in Eastern Maryland.[2] It could be prohibitively expensive.

Another alternative is a variation of Osborne's method, using aerial photographs to classify forest areas and estimate changes. Of course this method is possible only when repeat photo coverage of the area is available. The time interval between the two sets of photos must be short enough so that stumps are still in measurable condition, yet long enough so that a measurable proportion of the area is changed by drain.

This is the "photo method." The method was tried out in Maryland to determine if it could be adapted to forest-survey work. The area studied was Worcester County. Aerial photos of the area, made in 1938 and 1949, were available.

THE METHOD & THE TEST

The photo method of estimating drain consists of three principal steps:

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[1] Osborne, J. G. Growth, mortality, and drain--the 'continuous-inventory' system. U. S. Forest Service. 26 pp. (mimeo). Washington. 1947.

[2] Bickford, C. A., Chapman, R. A., and Caporaso, A. P. Report on cooperative test of 'continuous-inventory' forest survey system in Eastern Maryland. Northeast. Forest Expt. Sta. 31 pp. 1952.

- Distribution of area into drain classes, through photo-interpretation.
- Field examination of a sample from each class to obtain data on trees cut.
- Office computation of drain.

The photo drain classes were set up somewhat arbitrarily in advance as something usable, but not necessarily final. The classes used were:

A. No apparent cut, probably uncut.

B. No apparent cut, possibly cut.

C. Lightly cut, less than half of crown canopy removed.

D. Heavily cut, more than half of crown canopy removed.

All forested photo plots of the regular survey were used in the test. These points had been printed on the 1949 photographs (by multilith machine), and they were easily identified. Each point was compared with the identical point on the 1938 photographs to identify photo drain class.

(Each photo plot included an area of at least 1 acre surrounding the marked point. Each ground plot was 1/5 acre in the center of the photo plot.)

After the forest area was stratified this way, the next step was to obtain an estimate of mean volume of drain by classes. This was done through field examination of a series of plots, also a subsample of the plots classified on the aerial photographs. At each plot all stumps were classified by species; and diameter inside bark (d.i.b.) and height were measured. Data of cutting was recorded. Volume by species was estimated from these data, using regression equations of d.b.h. over stump height and stump d.i.b.

A few words about the sampling design: As pointed out, all forested photo plots of the regular forest survey were used. When the method is refined further, efficiency may be improved by a direct determination of the number of plots required for meeting a specified standard of accuracy.

The efficiency of this design depends on (1) how strongly volume per acre is correlated with photo drain class, and (2) cost of a ground plot in relation to cost of a photo plot. Efficiency is increased by a strong correlation. This design is more efficient when relative cost per ground plot is high.

The number of ground plots used in this test was determined from appropriate design formulas,[3] using estimates of mean volume and associated standard deviations by drain class. The accuracy standard was set arbitrarily at 15 percent of the total.

RESULTS

The results of this test use of the photo method in Worcester County, Md., are summarized in table 1. The numbers of plots by photo drain classes were obtained by photo-interpretation. The proportions and the areas in each drain class were computed from the number of plots and the total forest area.

Table 1.--Distribution of area by photo drain class, Worcester County, Maryland, 1938-49

Photo drain class	Photo plots	Proportion (P_i)	Area
	Number		Acres
A	426	0.792	135,543
B	12	.022	3,765
C	41	.076	13,007
D	59	.110	18,825
Total	538	1.000	171,140

The number of field plots used (table 2) was computed from the proportions shown in table 1, assumed means and standard deviations by classes, and a formula deduced from Neyman--

$$M_o = \frac{a(aA + b\sqrt{AB})}{AS^2}$$

in which a and b are calculated parameters (table 2), A is cost of a field plot, B is cost of a photo plot, and S is

[3] Neyman, J. Contribution to theory of sampling human populations. Jour. Amer. Statis. Assoc. 33: 101-116. 1938.

acceptable error. Thus--

$$M_o = \frac{49.128\left\{(49.128)(20) + \sqrt{19035}\ \sqrt{20(0.2)}\right\}}{20(10.65)^2} = 27.2$$

Numbers of field plots by classes were computed from an approximation of Neyman's formula 41--

$$M_i = \left(\frac{P_i S_i}{\Sigma P_i S_i}\right) M_o$$

In these calculations, $20 was used for A, 20 cents for B, and S is 15 percent of the over-all average (71) or 10.65 cubic feet.

Table 2.--Calculation of numbers of field plots required

Photo drain class	Assumed mean	Assumed standard deviation	*$P_i S_i$	$X_i - \bar{X}$	$P_i(X_i - \bar{X})^2$	$\frac{P_i S_i}{\Sigma P_i S_i}$	Field plots	
	X_i	S_i					Calculated	Used
	Cubic feet	Cubic feet					Number	Number
A	1	1	0.792	-70	3881	0.016	0.43	2
B	2	3	.066	-69	105	.001	.03	2
C	200	200	1.52	-129	1265	.031	.84	2
D	500	425	46.75	-354	13784	.952	25.92	22
Total	--	--	49.128=a	--	19035=b^2	1.000	27+	28

*P_i is same as in table 1. $\bar{X} = \Sigma P_i X_i = 71.036$.

Drain for the entire county was estimated from plot average by classes, expanding the data by the factor class area—plot area. Estimated drain for Worcester County is shown in table 3.

The sampling error for these estimates was computed from Neyman's formula 40, as shown in table 4.

National forest-survey procedures require that growth of trees cut be separated from commodity drain. This was done (table 5) by use of the simple interest formula, using calculated growth percentage as the rate.

DISCUSSION

Disadvantages

In the forest survey, commodity drain must be separated into two parts: what is used and what is left as waste. The part that is used must be broken down further into particular commodities.

Use of the photo method does not provide information for doing this; and some sort of extra study would be needed if the photo method were used.

Table 3.--Estimated volume of drain due to cutting, Worcester County, Maryland, 1938-49

Photo drain class	Class of material		Volume	
			Board feet	Cubic feet
A	Hardwoods	Poletimber	--	1,304,603
B	Softwoods	Poletimber	--	14,443
		Sawtimber	4,875,675	929,956
C	Hardwoods	Sawtimber	30,540,436	4,227,275
	Softwoods	Sawtimber	20,394,976	3,773,331
D	Hardwoods	Poletimber	--	1,102,868
		Sawtimber	27,509,679	4,400,565
D	Softwoods	Poletimber	--	3,036,310
		Sawtimber	81,123,714	17,065,370
Total, all classes	Hardwoods	Poletimber	--	2,407,471
		Sawtimber	58,050,115	8,627,840
		Total	58,050,115	11,035,311
	Softwoods	Poletimber	--	3,050,743
		Sawtimber	106,394,365	21,768,657
		Total	106,394,365	24,819,400
	All species	Poletimber	--	5,458,214
		Sawtimber	164,444,480	30,396,497
		Total	164,444,480	35,854,711

This problem might be solved by compiling the best available estimates for each commodity and for logging waste (from Census data, industrial reports, state records, etc.); then proportions worked out of these data could be applied to separate the photo drain data into commodity drain and logging waste, and to distribute the commodity drain among

the various commodities. The difference between the production data and the photo drain estimates could be ignored.

Another disadvantage is that repeat photo coverage for the area may not be available. It is evident that photo coverage is too expensive to purchase for the sole purpose of estimating drain. However, it should be possible to get adequate data from sample photo coverage--if the sample were unbiased. Sample strips of photography, with end lap but no side lap, might be a workable compromise.

Advantages

As Osborne pointed out, any method of estimating drain that is based on re-measurement eliminates at once the reporting errors, removes the problem of accounting for tim-

Table 4.--Calculation of sampling error

Photo drain class	P_i	$\bar{X}_i$	S_i	P_iS_i	$\bar{X}_i-\bar{X}$	$(\bar{X}_i-\bar{X})^2$	$P_i(\bar{X}_i-\bar{X})^2$
A	0.792	2	4	3.168	-40	1,600	--
B	.022	50	45	.990	8	64	--
C	.076	123	69	5.244	81	6,561	--
D	.110	272	199	21.890	230	52,900	--
Total	1.000	41.952	--	31.292	--	--	7,586.242

$$S^2 = (171140)^2\,(5)^2\left\{\frac{(31.292)^2}{28} + \frac{7586.244}{538}\right\} = 35,931,622,029,280;\ \text{and}$$

S = 5,994,299 cubic feet, which is 16.7% of total estimated drain from cutting.

Table 5.--Separation of drain[1] into initial volume and growth of cut trees

Photo drain class	Volume when cut - Drain		Growth of trees cut		Initial volume	
	Cubic feet	Board feet	Cubic feet	Board feet	Cubic feet	Board feet
A	1,304,603	--	304,972	--	999,631	--
B	944,389	4,875,675	268,570	1,631,500	675,819	3,244,175
C	8,000,606	50,935,412	1,474,994	10,912,873	6,525,612	40,022,539
D	26,605,113	108,633,393	4,315,646	22,981,416	21,289,467	85,651,977
Total	35,854,711	164,444,480	6,364,182	35,525,789	29,490,529	128,918,691

[1]These data may be distributed by classes of growing stock shown in table 3; they may also be separated by species, if needed, insofar as species may be identified from a stump.

ber moved in or out across state lines, removes the problem of variations in wood utilization, and simplifies calculation of the sampling error.

Data collected under the standard forest-survey method contain reporting errors due to bias, etc., and there is not much that can be done about them except hope they are more or less compensating. Use of the photo method would eliminate reporting errors as a factor in estimating drain.

Use of the photo method would also eliminate the problem of estimating the volume of timber products moved in or out across state lines.

When commodity data are used in estimating drain, one must recognize that actual utilization of the trees may not agree with the forest survey's theoretical limits of merchantable volume. Stumps may be higher or lower, top utilization may be greater or less, small trees may be knocked down or otherwise destroyed during the logging. Use of the photo method would permit a direct estimate of drain that would be closely comparable to inventory volume. Thus a wood-utilization study would not be essential to an estimate of total drain.

The volume of timber included in the standard forest-survey inventory may be reduced by noncommodity cutting, fire, windthrow, and possibly other causes. Use of the photo method would put estimates of drain from these causes on a substantial and objective basis. Estimates of volume lost could be based on measurement of the remaining evidence.

With the standard forest-survey method, the sampling error is estimated from the sum of the variances by commodities. For each commodity there may be sampling errors in both commodity production and in logging waste; and these errors are additive. There may also be sampling errors in estimates of timber moved in or out of the area. Calculating sampling errors for the standard survey method is a cumbersome task. But for the photo method, calculating the sampling error is elegantly simple.

Cost

It was originally feared that use of two sets of aerial photos to estimate drain class might be cumbersome and costly. These fears proved groundless. The photo drain classes were easier and cheaper to identify on the photos than the stand-size or volume classes used in the standard forest-survey inventory.

Photo-interpretation of the 538 plots used was done in 29 man-hours at an estimated average cost of 11 cents per plot. This is about half the average cost for the standard inventory.

Field costs were estimated at $401.50. This included 156 man-hours, 738 miles of automobile travel, and travel expenses for a 2-man crew. For this expenditure two plots[4] were examined at each of 28 locations. The average cost per location was $14.30, in comparison with an average cost of about $35 for standard inventory plots.

No record was kept of compilation costs, but it is certain they would be small in comparison with those of the standard forest-survey drain method, which is mainly a manual chore. With photo drain classes the compilation procedure would parallel the inventory procedure, and greater use could be made of punch-card techniques.

Cost Comparisons

The most important comparison between the photo method and the standard forest-survey method and Osborne's continuous-inventory system is the total cost required to achieve a specified standard of accuracy.

Exact comparisons are difficult to make. The standard forest-survey method has been used only for estimating drain for a particular year, whereas the photo method may be used to estimate drain either for a single year or for a period of several years. Adjusting the standard method to provide data on periodic drain would make it more costly. The photo method, on the other hand, costs about the same for estimating annual drain as for periodic drain.

If all or a major part of the required data were provided by other agencies (a state, for example), it is evident that use of the standard method would cost less than full use of the photo method.

Osborne's continuous-inventory system, modified to use 1/10-mile strips, appears to cost about four times as much as either of the other two methods.

The choice between the standard forest-survey method and the photo method will usually be decided on the basis of

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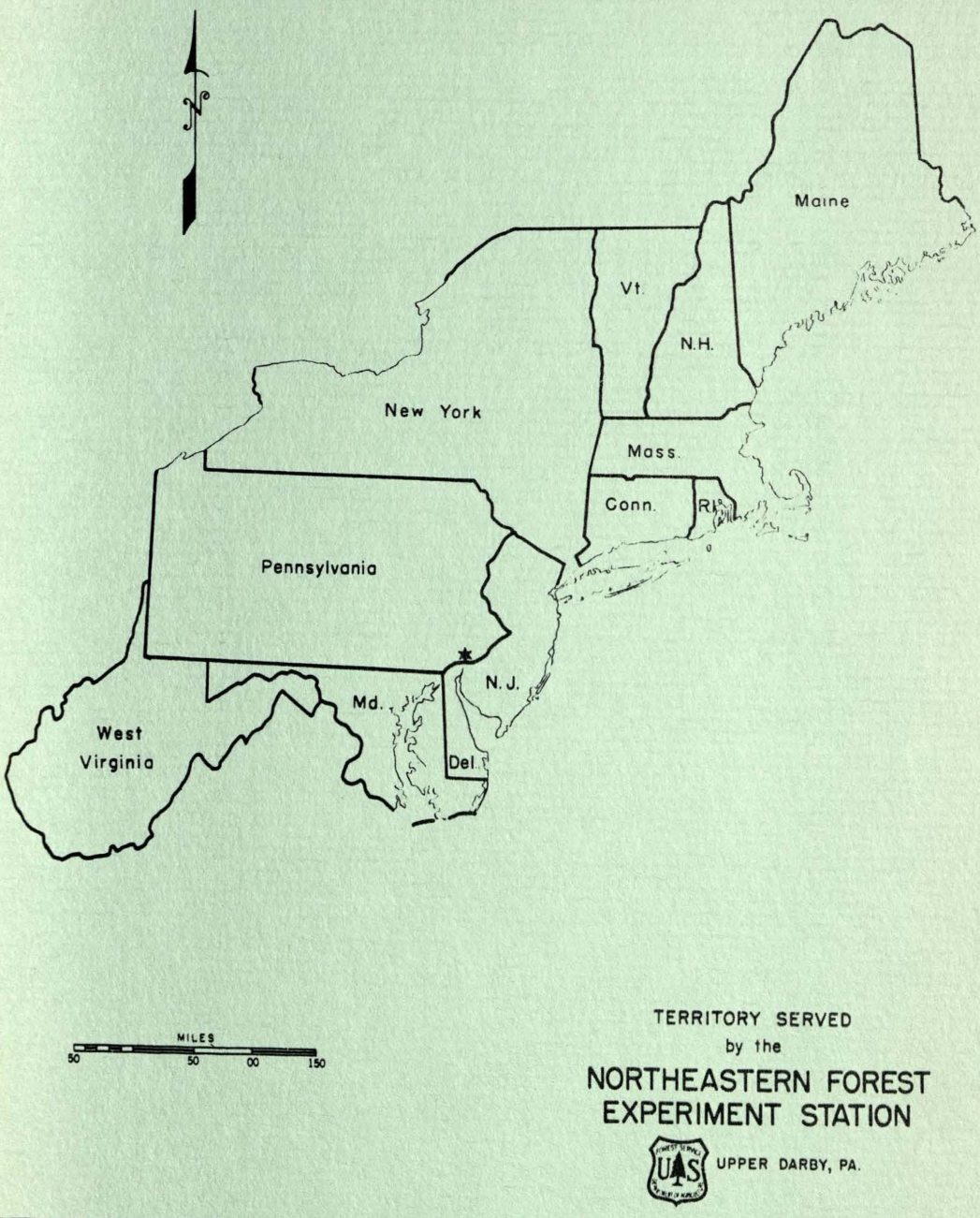
[4] Ordinarily 1 plot per location would suffice; 2 were used here to get a better measure of variation.

exactly what kind of drain information is needed and what information is already available from other sources.



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